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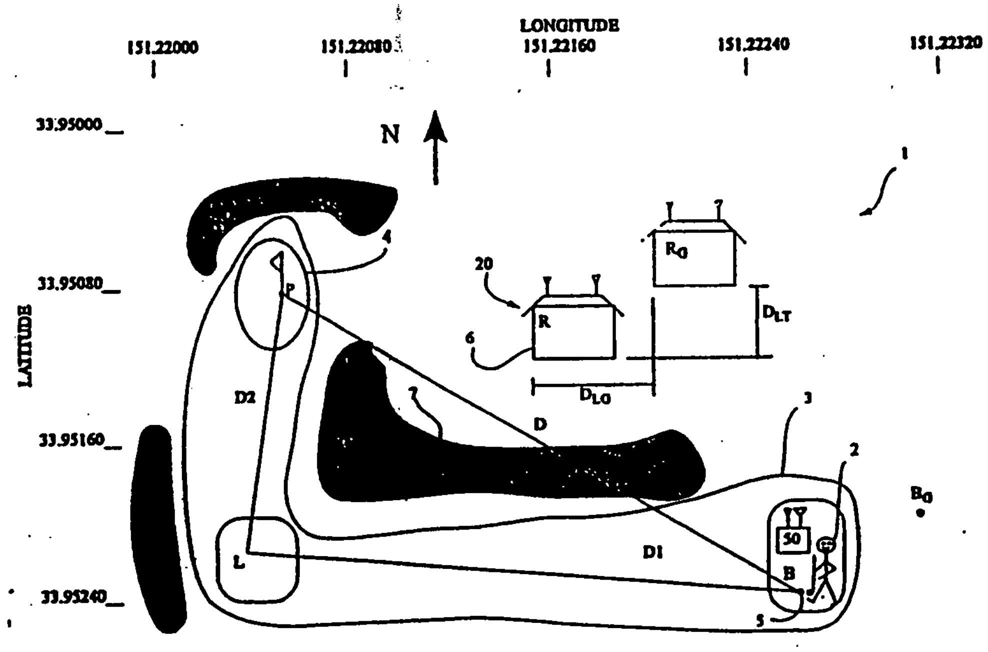

(57) Abstract

A distance measuring system is disclosed in which a user (2) in possession of a portable distance calculator (50) can determine the distance (D1, D) between an actual position (B) and a fixed position (L, P). Satellite position data of the fixed position (L, P) is determined periodically and supplied to the calculator (50). The calculator (50) includes a satellite position receiver (51) and a processor (54) which permit the distance (D1, D) to be determined. In a preferred embodiment error correction is performed by determining a satellite differential position error at a known survey reference location (R) and supplying the error to the calculator (50) for correction of the actual position (B) and, where necessary, the fixed position (L, P).

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A DISTANCE MEASURING SYSTEM

FIELD OF THE INVENTION

The present invention relates to distance measurement and, in particular, discloses a method and appears which is used to determine the distance between a variable position and one or more of a number of fixed positions.

BACKGROUND ART

In many fields of endeavour, such as surveying and navigation to name but two, it is necessary to determine distances, preferably quickly, accurately and economically. Hitherto, line of sight distances have been determined using lasers and other optical apparatus which, whilst providing a highly accurate result, are often expensive and cumbersome to use.

One particular example of where known optical devices are poorly adapted for use is where, during the course of a game of golf, it is necessary to determine the distance between the golf ball and the pin position (the "hole"). This is required so that the golf player can choose an appropriate club with which the ball can be struck. It is important that the distance be determined with some level of accuracy in view of the different distances afforded by different clubs.

Typically, a golfer can estimate the distance using his best judgement. This "traditional" method is that internationally accepted by the sport at competition levels, but at non-competitive levels, some players prefer a more accurate method by which their game can be improved. Generally, an accuracy better than 10 metres is required as this, for example, can be the difference in range between a 7 and 8 iron. It is common practice to pace out the distance from the golf ball to the pin on a golf course. This method is very time consuming and frustrating for all players, as it slows down the throughput of the number of players on the course at one time.

It is an object of the present invention to substantially overcome, or ameliorate, the problems associated with the prior art through provision of a distance measuring system which permits the taking of distance measurements relatively accurately and conveniently.

SUMMARY OF THE INVENTION

In accordance with one aspect of the present invention there is disclosed a method for determining the distance between a variable position and one or more of a plurality of fixed positions, said method comprising the steps of obtaining first satellite position information of one of said fixed positions and supplying said first information to a user for use at said variable position, said user obtaining second satellite position information of said variable position, and subsequently calculating the distance between said variable position and said fixed position using said first position information and said second position information.

Preferably, the method also includes the step of obtaining third satellite position information of a reference location and comparing same with survey position information of said reference location to determine a satellite position information differential error, said error being supplied to said user to permit correction of errors in said first and second position information, prior to calculating said distance.

In accordance with another aspect of the present invention there is disclosed a distance measuring system comprising a base station having a control means and a data transmitter means, said control means being configurable with first satellite position information obtained from a (first) portable satellite position receiver, of one or more fixed positions, said first position information being communicable by said data transmitter means to one or more

portable distance calculators, each said distance calculator comprising a (second) satellite position information receiver, a data receiver means means adapted to receive data from said data transmitter means, and a processor means, said processor means accepting said first satellite position information of a fixed position selected by a user of said calculator and actual position information provided by said second satellite position receiver, and subsequently calculating the distance therebetween and presenting said distance for consideration by said user.

Preferably, the system further includes a third satellite position information receiver arranged at a reference location and configured to periodically provide satellite position information of said reference location whereby said control means compares a pre-determined survey position of said reference location with said satellite position of said reference location to determine a satellite position information error, said error being supplied to said portable distance calculator(s) for correction of said satellite position information used by said calculators.

Generally, the fixed positions can be golf pin locations and the variable position that of the golf ball, for example.

BRIEF DESCRIPTION OF THE DRAWINGS

A number of preferred embodiments of the present invention will now be described with reference to the drawings in which:

Fig. 1 schematically illustrates one hole of a golf course configured with the preferred embodiments;

Fig. 2 is a schematic block diagram representation of one embodiment of the base station of Fig. 1;

Fig. 3 is a schematic block diagram representation of one embodiment of the portable distance calculator of Fig. 1;

Fig. 4 is a schematic block diagram representation of another embodiment of the portable distance calculator of Fig. 1;

Figs. 5 and 6 illustrate various attributes and errors associated with the GPS satellite system;

Fig. 7 is a schematic block diagram representation of another embodiment of the base station of Fig. 1; and

Appendix 1 shows a pseudo-code computer program used to implement the preferred embodiment; and

Appendix 2 is an illustrative example of distance calculation.

BEST AND OTHER MODES FOR CARRYING OUT THE INVENTION

As seen in Fig. 1, a golf course 1 is shown in which a golf player 2 is situated on a fairway 3 and about to "tee off" so as to approach a green 4. The green 4 includes a pin position P which is seen to be at a lineal distance D from a position B of a golf ball 5. Because of the existence of an obstruction 7 (trees, for example), the fairway 3 "dog-legs" at a position L which gives the actual distance to the green 4 being the sum of two distances D1 and D2, as illustrated. The position L marks an area at which the golfer's first stroke is intended to land and for which the distance D1 must be determined.

The golfer 2 is able to calculate the distance D1 using a portable distance calculator 50 which is operated at the location B. The portable distance calculator 50 receives position information from navigational satellites orbiting the earth, as well as data received from a base station 20, which can be arranged at a club house 6. The base station 20 resides at a reference position R whose position on Earth is accurately known from survey data that is obtained by usual survey methods, and which are quite accurate.

There have recently become available satellite position receivers which can provide position information in latitude, longitude and elevation using navigational

satellite systems, such as the Global Positioning System (GPS) satellite network. GPS receivers are well known in the art and are typically used for navigation on land and at sea.

Referring now to Fig. 2, the base station 20 includes a GPS receiver 21 configured at the known reference location R. The GPS receiver 21 supplies GPS position information of the reference location R to a control unit 23. An input buffer 24 of the control unit 23 provides interconnection between the GPS receiver 21 and a controlling processor 26. The control unit 23 also includes a memory unit 29 having a number of memory locations dedicated for specific blocks of data used in the system. The control unit 23 is configured firstly to obtain the GPS position of the reference location R by means of position information output from the GPS receiver 21 and record same in a predetermined memory location 30. The GPS position in the memory location 30 is continually updated and so can vary according to the error in the satellite system at that latitude, longitude and altitude, at that particular time of day. The memory unit 29 is additionally pre-programmed with the actual survey position of the reference location R which is stored in a memory location 33.

Using the survey position 33, and the continually updated GPS position 30, the processor 26 can calculate, and continually update, a GPS differential error 31 indicative of the actual error in the position information received from the GPS receiver 21.

Returning to Fig. 1, a ghost position R_G of the reference location R is shown which represents the GPS position in the memory location 30 provided by the GPS receiver 21. In the example illustrated:

$$R = 33.95080°S, 151.22160°E, \text{ and}$$
$$R_G = 33.95040°S, 151.22200°E.$$

This value gives a differential latitude error

$$D_{LT} = -0.00040°,$$

and a differential longitude error of

$$D_{LG} = +0.00030°.$$

These values together form a GPS differential error which is calculated by the processor 26 and stored in a memory location 31.

The control unit 23 is also provided with a input keyboard 27 and a display 28, through which a user can input satellite recorded values of the pin position P and the position L. This information can be programmed into the control unit 23 in several ways. One alternative is a hardware data link, from a hand held data logger including an integral GPS receiver (ie: one of the portable calculators 50), that would be used to obtain the pin position P, and any "dog leg" positions L.

At most golf courses, the actual location on the green of each pin is changed from time to time as determined by the green keeper. Where this occurs, it is necessary for the pin positions 32 recorded in the control unit 23, be updated contemporaneously so that the system can operate accurately. This update can be performed once each pin is repositioned with the new positional data being entered into the control unit 23 and subsequently the calculator 50 prior to the commencement of play.

The base station 20 is configured, using a radio data transmitter 22 to broadcast/transmit data around the golf course indicative of the position of each of the pins and any "dog legs". The GPS differential error 31 is also transmitted so that positional data errors about the golf course can be corrected (to be described). The radio data transmitter 22 can be configured to operate on any useful frequency, such as 173 MHz, and can use any method of modulation suitable for transmitting data, such as frequency modulation (FM).

Turning now to Fig. 3, the portable distance calculator 50 includes a radio data receiver 52 adapted to receive signals transmitted from the transmitter 22. Data received by the receiver 52 is supplied to a controlling processor 54 via an input buffer 53. The data received is stored in a memory unit 57 that comprises locations for a product code 58, a personal identification code (PIC) 59, offset error data 60, pin position data 61, and the GPS differential error 62. The portable distance calculator 50 also includes its own GPS receiver 51 which allows the determination of the GPS position of the current position of the ball 5. In Fig. 1, the GPS position of the ball 5 is the ghost position B_G, in a corresponding manner to the GPS position of reference location R being R_G. The GPS position B_G of the ball 5 is stored in a memory location 63 in the memory unit 57. In this configuration, the distance calculator 50 can, using a selected pin position 61 (e.g. pin 2 dogleg) and the GPS position B_G of the ball 5, determine the distance D1 between the position B of the ball 5 and the position of the dog leg L. The same procedure can be repeated for each stroke required to reach the golf pin P.

The distances are calculated using trigonometry, and also taking into account the change of longitude grid distances away from the equator. This corrects for the earth's non-spherical shape. The longitude/latitudes are then converted into metres or yards as some players prefer.

It is necessary to correct for the earths curvature to obtain accurate results. Similarly it is necessary to convert the navigation units into metres (or yards) to give purpose to the distances calculated. The pseudo-code of Appendix 1 shows a simplified version of performing such calculations and Figs. 5 and 6 and the following give a worked example. The diagram of the Earth in Fig. 6., shows that the longitude lines vary in distance apart from zero at the poles to maximum at the equator. The relationship for

this is a Cosine function of the latitude, zero degrees being the equator and 90 degrees being the poles.

COS(0 deg)=1 COS(90 deg)=0

It is known that the earth is not uniformly circular upon its axis, and in highly accurate navigational situations this would need to be taken into account. However, in the preferred embodiment distances are measured across only relatively short distances, and accordingly any differences encountered are irrelevant. Hence, the use of the WGS-84, World DATUM for the equatorial radius. WGS-84 states the radius at the equator is 6378.137 km. Converting this into metres at the resolution used by the system (0.00001deg).

Longitude metres per 0.00001 degree at the equator.

Lgeq =((2*PI*6378137)/360)*0.00001=1.11319 metres.

The Polar radius is equal to 6357.000km.

Latitude metres per 0.00001 degree.

Lt=((2*PI*6357000)/360)*0.00001=1.10951 metres.

Appendix 2 gives an example of distance calculation based on the above principles.

These are the smallest units used by the system and provide a 2-5 metre accuracy (for 50% of readings) for the system, as a whole.

Bearing calculations are used in determining the direction that the ball was hit, and for the statistical purpose of calculating the distance the ball was "Hooked" or "Sliced" away from the 'ideal' centre of the fairway.

On 25th March 1990, the United States Department of Defence, who operates the GPS satellites, formally implemented Selective Availability (SA). Selective Availability is a method of denying unauthorized, nonmilitary, GPS users high position accuracy with coarse acquisition code (C/A code). The reason behind this is so

that they are not supplying the "enemy" with such a useful tool, which could be used against them. However the Department of Defence has stated that the policy of Selective Availability would be reviewed annually in an effort to increase the accuracy available as conditions warrant.

The GPS has a number of errors which need be considered in various applications. Those errors are:

1. Satellite Ephemeris prediction errors;
2. Satellite clock prediction errors;
3. Ionospheric delay errors;
4. Tropospheric delay errors as they appear at the reference station;
5. Artificial errors induced by Selective Availability (SA) techniques;
6. Differential tropospheric delay error, if desired; and
7. Reference station clock offsets.

The first five of these errors are common to both the user 2 and the base station 20, although this commonality is to be reduced (except for clock prediction errors and certain SA errors) as the distance between the user 2 and the base station 20 increases. The last two are provided by the reference station in order for the user to correct for errors that are not in common; the last one only affects the user's ability to determine absolute time.

Accordingly, the differential error message output from the base station 20 provides as its primary correction a number pseudorange corrections. The correction message output from the base station 20 contains data for all the satellites in view of the base (reference) station 20. The pseudorange correction is a predicted correction. It will diverge from the proper correction as it "grows old". Because of this characteristic, the pseudorange correction is preferably updated and transmitted as often as possible.

The user equipment preferably updates the corrections accordingly.

A range rate correction is also provided and is designed to compensate for the predicted rate of change of the pseudorange correction. This is an attempt to "extend the life" of the pseudorange correction as it "grows old".

In the illustration of Fig. 1, the GPS receiver 51, in attempting to determine the position B, as stated earlier actually provides the ghost position B_G.

Fig.5 shows a representation of the GPS orbiting satellites or space vechicles (SV's), the ionosphere, the reference station and the user. Also shown is a differential zone that can have a radius in the order 100's kilometres or more. Due to the fact that the satellites SV orbit the earth at altitudes of 20,183 km. Pythagoras theorem can be used to determine the angle theta subtended between the user and the reference location. It is apparent that the ratio of a few hundred kilometres to 20,183 km is huge, and for this reason, the GPS specification states that the differential error at any one time is constant for a radius of about 100 km about the location at which the position is measured. Therefore, GPS error 31 obtained at the survey location R is indicative of the error around the entire golf course.

Accordingly, the GPS error 62, comprising D_{LT} and D_{LG}, can be used to correct the ghost position B_G to give the actual position B. This is obtained by subtracting the differential error from the measured position. Accordingly, for Fig. 1:

$$B = B_G - (D_{LT}, D_{LG})$$
$$= (33.95200, 151.22310) - (-0.00040, 0.00030).$$

Giving B = 33.95240°S , 151.22280°E

The positional data of P and L can be corrected in a similar manner to give

P = 33.95080°S, 151,22060°E; and

L = 33.95190°S, 151.22030°E.

Using the positions B and L, the first distance D1 can be calculated trigonometrically where the latitude difference is 0.00050° and the longitude difference is 0°00250.

Using the latitude and longitude corrections indicated above, the distance D1 can be calculated as follows:

$$D1 = \sqrt{((50 \times 1.10951)^2 + (250 \times 1.11319)^2)}$$

$$= 278.3 \text{ metres.}$$

The distance D2 is calculated once the ball 5 has landed near the dog-leg.

Because a golf course is small, in a global sense, the GPS error 31 obtained at the survey location R, is indicative of the error around the entire golf course.

Because the golf course is basically a grid on which each of the pins are mapped, any other location can also be stored that can be useful to the player. If the fairway had a dog leg approach to the pin, the ideal dog leg position can also be mapped, so that the distance and bearing to the ideal dog leg can be displayed.

Furthermore, it is possible to log any new position and actually calculate the distance at which the last "shot" was hit. This can also be useful for determining an average distance hit for each club, for example.

It is envisaged that the distance calculators 50 are hired either from the golf club or used with the permission of the golf club, having paid some form of user licence. For example, on entering the golf course, the golf player 2 can pay an additional fee for the use of a portable distance calculator 50. Alternatively, if the player 2 has his own calculator 50, an alternative fee can be provided. Upon payment of the fee, the golf player can be provided with a daily personal identification code (PIC) 59 with which the player 2 must enter into the keypad 55 so as to enable use of

the data received from the base station 20. The personal identification code entered into the keypad 55 is checked against that received and stored in memory location 59 and if both coincide, the calculation of the distance is permitted. The product code 58 permits use of distance calculators 50 on the golf course 1 where the base station 20 has a corresponding or complementary code. This prevents unlicensed or unauthorized use.

In use, the system shown in Figs. 1 to 3 must permit operation over long periods of time. In this manner, the data transmitter 22 being arranged at a club house or other like location, is configured to transmit continually, so that golf players are not inconvenienced when taking distance measurements. To undertake a distance measurement, the golf player 2 stands over the golf ball 5 and enters the daily personal identification code 59 once at switch on into the keypad 55. The entry of the code wakes the distance calculator 50 from a quiescent, battery power saving state and energizes the GPS receiver 51 and the data receiver 52. When the data receiver 52 detects data transmitted from the transmitter 22, the PIC 59 is initially checked, and if they correspond, the remaining pin position data 61 and GPS error are loaded into the memory 57. When both the pin position 61 and the GPS position 63 are stored in memory 57, the processor 54 indicates, using the display 56 that positional data is available and the golf player need then only enter the particular pin position required. For example, if the golf player is on a hole, pin position 9 is entered. The processor 54 then selects the position of pin 9 and the present GPS position 63, corrects each of those positions using the GPS error 62, and then calculates the distance D between those two positions which is displayed on the display 56. The golf player 2 can then select an appropriate club so as to best cover the distance D.

The preferred embodiment described above can provide a distance measuring accuracy of about 2 to 5 metres or better using both averaging of the GPS receive data and calculation of the differential error.

Fig. 4 shows a specific architecture of a portable distance calculator 100, complementing the schematic of Fig. 3, and has a microcontroller 101 which includes a boot EPROM programmed with the pseudo-code of Appendix 1.

A line driver/receiver 102 permits interconnection between the microcontroller 101 and a personal computer thereby permitting direct programming of the pin positions prior to the commencement of play, in which case the personal computer can be configured as the control unit 23. The pin positions are stored in memory comprising Flash RAM 103, such as a memory card, and static RAM 104.

User interface is provided by a keypad matrix 105 having an associated keypad decoder 106, and an LCD display 107, driven via a LCD controller 108 having a dedicated LCD SRAM 109.

The calculator 100 is powered by a battery power supply 110 which outputs two voltages V1 and V2, nominally +5V and +1.5V, respectively.

The V1 supply powers all digital circuitry within the calculator 100. The V2 supply is input into a data link antenna and receiver 111. The line driver/receiver 102 also includes a voltage inverter which creates further supplies V3 and V4 (nominally +10V and -10V respectively). V3 and V4 supply a low noise preamplifier 112 which buffers signals output from the receiver 111 to a modem 113.

GPS signals are detected by a FOG antenna and amplifier 114 which outputs to a GPS receiver 115 which demodulates the received signal to output GPS position data.

The modem 113 and GPS receiver 115 each transmit and receive data to/from the microcontroller via a dual universal asynchronous receiver/transmitter (DUART) 116.

Crystals 117 and 188 provide clock signals for the transmission of data to/from and about the calculator 50.

Fig. 7 shows an alternative arrangement of a base station 150 which is configured with a differential GPS reference station 151. The station 151 can be a Trimble Reference Locator II recently manufactured by Trimble Navigation of Sunnyvale, California, U.S.A. The reference station 151 is autonomous device arranged to calculate and transmit differential corrections to mobile GPS receivers. That station 151 has a nine channel architecture which enables it to track and generate precise differential corrections for all GPS satellites in view at any one time. Accordingly, a possible nine different error readings can be transmitted which enables the calculator to select the error corresponding to the satellite from which it receives positional data. Alternatively, an average of the nine errors can be transmitted. The differential corrections are output on an RTCM SC-104 standard format data link to a modem 152 which transfers same to an FM transmitter 153 for broadcasting to the portable calculators 50,100. The GPS receiver 115, when taking positional measurements, obtains data from a number (up to 6) of the GPS satellites and each group of satellite data can then be corrected with corresponding error data obtained via the reference station 151. from the corrected individual satellite data, the actual position is calculated.

It will be apparent from the foregoing that a golf player can readily obtain distance information between any location on the golf course, and any particular pin hole.

For example, the distance calculator 50 can also be used as a personal data base with which a golfer can calculate and compare one's own performance over a particular course. For example, the calculator 50 can be readily adapted to calculate the successive distance to the hole, for example, over a par 5 hole. Additionally, the

calculator 50 can be pre-programmed with average distance hits for a particular golfer with specific clubs. In this manner, depending on the distance calculated, the calculator 50 can be used to recommend a particular club suiting the next particular shot to be played. A further modification is to correct for errors in altitude and hence provide more accurate distance measurement over hilly golf courses. It is also possible to incorporate directional bearing information to enable the golfer to determine the direction of the pin relative to his stance, whether or not the pin is visible to the golfer.

Furthermore, because the device 50 is a calculator of sorts, in that it has a keypad and display, it is possible to incorporate into the device an electronic score pad for use during the game, keeping and adding scores as required. Also the LCD display 107, because it is a 2-dimensional pixel array, can be configured as a graphical display with map capabilities for a graphical display of each fairway. Any map data can be supplied directly to the calculator 100 with the pin and dogleg positions via the personal computer connection and into the SRAM 104, or via a memory card operating as the Flash RAM 103.

It will be apparent that the system disclosed herein is not only applicable to short range, line-of-sight distance measurement such as in golf, but can be used in a variety of arts, including bushwalking, for example. Furthermore, the system has ready application to the surveying arts and in particular in the quick and accurate laying out of new markings in a previously survey region, at which one or more base stations can be arranged.

The system also has application in fleet management, for example in creating record of distances travelled from base locations and the spread of vehicular resources.

Other applications include aircraft systems where the present system can be used to supplement outer markers in

controlled air space. Also, crop dusting operators can accurately gauge the exact location for such operations thus preventing waste of material and possible damage to adjacent environments.

Furthermore, at an anticipated cost of A$500-$1000 (1992) per calculator, the system represents a cost effective alternative to optical systems without the expense of set-up times of such systems, and their inherent fragility. Accordingly, the present system offers an inexpensive, and easy to use navigation system.

Furthermore, if the calculator 50,100 is used to record the pin and dogleg positions prior to the commencement of play, it is preferred that those positions be error corrected as they are taken, and not when entered into the control unit 23 in the base station 20. This will prevent any change in the error affecting the accuracy of the fixed position data.

The foregoing describes only one embodiment of the present invention, and modifications, obvious to those skilled in the art can be made thereto without departing from the scope of the present invention.

APPENDIX 1

```
/
****************************************************************
****
    *                 Pinranger Australia Pty. Ltd.              *
    *               Golf Distance Measuring system.              *
    *                                                            *
    *                    Written by Tom Gunthorpe.               *
    *                          Copyright 1992                    *
    ************************************************************
*******/
     PI   3.1415926535898
     D2R  PI/180.0
     R2D  180.0/PI

    /* Pin location information (sample only) */
    /* Two dimensional array, (18 arrays of 2 elements) */

    /* Degrees in decimal format */
    pin_table[18][2] =
    {{-33.96050,151.22320},{-33.96035,151.22333},
     {-33.96058,151.22363},{-33.95997,151.22457},
     {-33.96070,151.22275},{-33.96000,151.22333},
     {-33.96167,151.22500},{-33.96083,151.22417},
     {-33.96200,151.22583},{-33.96133,151.22667},
     {-33.95833,151.22500},{-33.96167,151.22167},
     {-33.96045,151.22353},{-33.95500,151.22167},
     {-33.95583,151.22417},{-33.95333,151.21833},
     {-33.95167,151.23000},{-33.96050,151.22318}};

    /* Perform mathematical corrections and conversions */
    latlon()
    {
```

```
            lat1 = pin_table[pinnum][0];/* Stored in degrees
*/
            lon1 = pin_table[pinnum][1];
            lat2 = latitude;                         /* Values
from GPS  */
            lon2 = longitude;

        /* Calculate Latitude and Longitude differences in
meters.*/
        /* Longitude difference and corrections */
            a_axis = 6378137.0;             /* WGS84 default */
            londif = (lon1-lon2) * (((a_axis * 2.0 * PI)/360)
* cos(latitude));

        /* Latitude difference */
            p_axis = 6357000.0;             /* The Polar radius
= 6357km */
            latdif = (lat1-lat2) * ((p_axis * 2.0 * PI)/360);
        }

        /* Calculate the Range between the two points */
        /* range = sqrt(((lat1-lat2)^2)+((lon1-lon2)^2)) */

        range(float latdif, float londif)
        {
            rng = sqrt((latdif * latdif) + (londif * londif));
            printl("Range ");
            printd(rng);
            return;                                  /* 1 yard
= 0.9144 metres */
        }

        /* Calculate the Bearing from the standing location */
        /* to the Pin, in degrees clockwise from true North. */
```

```
bearing (float latdif, float londif)
{
      if (latdif > 0.0 && londif > 0.0)
                brg = atan(latdif / londif);
      else if (latdif < 0.0 && londif > 0.0)
                brg = atan((latdif / londif) * -1.0 ) ÷
(PI/2);
      else if (latdif < 0.0 && londif < 0.0)
                brg = atan(latdif / londif) + PI;
      else if (latdif > 0.0 && londif < 0.0)
                brg = atan((latdif / londif) * -1.0 ) -
(PI/2) + PI;

      bg = brg * R2D;                  /* Convert radians
to degrees */
      printl("Bearing  ");
      printd(bg);
   return;
}
```

APPENDIX 2

First co-ordinates: lat -33.96045
lon 151.22353

Second co-ordinatges: lat -33.95853
lon 151.22789

abs delta lat = -33.96045 - -33.95985
= 0.00060 * 10000
= 60

abs delta lon = 151.22353 - 151.22412
= 0.00059 * 10000
= 59

Longitudinal convertion to metres.

$$Lg_{lt} = COS(lat) * Lg_{eq}$$
$$= COS(33.96) * 1.11319$$
$$= 0.8294277 * 1.11319$$
$$= 0.92331$$

delta lat(metres) = 60 * 1.10951
= 66.5706metres

delta long(metres) = 59 * 0.92331
= 54.47529metres

distance between two points =
SQR(((delta lat)^2)+((delta lon)^2)

= SQR(((66.5706)^2) + ((54.47529)^2))
= 86.02 metres

CLAIMS:

1. A method for determining the distance between a variable position and one or more of a plurality of fixed positions, said method comprising the steps of obtaining first satellite position information of one of said fixed positions and supplying said first information to a user for use at said variable position, said user obtaining second satellite position information of said variable position, and subsequently calculating the distance between said variable position and said fixed position using said first position information and said second position information.

2. A method as claimed in claim 2, wherein t e step of supplying said first information comprises radio frequency transmission for complementary reception of said first information at said variable position.

3. A method as claimed in claim 1, wherein the step of supplying said first information comprises a direct transfer of said information to said user prior to the use thereof at said variable position.

4. A method as claimed in claim 1, 2 or 3, comprising the further step of obtaining a third satellite position information of a reference location and comparing same with survey position information of said reference location to determine a satellite position information error, said error being supplied to said user to permit correction of errors in said first and second position information, prior to calculating said distance.

5. A method as claimed in claim 4 when dependent on claim 2, wherein said error is periodically redetermined and retransmitted to said variable position thereby permitting real-time correction of at least said second position information.

6. A distance measuring system comprising a base station having a control means and a data transmitter means, said control means being configurable with first satellite

position information obtained from a (first) portable satellite position receiver, of one or more fixed positions, said first position information being communicable by said data transmitter means to one or more portable distance calculators, each said distance calculator comprising a (second) satellite position information receiver, a data receiver means adapted to receive data from said data transmitter means, and a processor means, said processor means accepting said first satellite position information of one of said fixed positions selected by a user of said calculator and actual position information provided by said second satellite position receiver, and subsequently calculating the distance therebetween and presenting said distance for consideration by said user.

7. A system as claimed in claim 6, wherein said data transmitter means comprises a radio transmitter and said data receiver means comprises a complementary radio receiver.

8. A system as claimed in claim 6, wherein said data transmitter means comprises a hardware interconnection port connectable to a complementary port in said data receiver means thereby permitting direct communication of said first position information therebetween.

9. A system as claimed in claim 6, further comprising a third satellite position information receiver arranged at a reference location and configured to periodically provide satellite position information of said reference location to said control means whereby said control means compares a pre-determined survey position of said reference location with said satellite position information of said reference location to determine a satellite position information differential error, said error being supplied to each one of said calculators for correction of satellite position information used by said calculators.

10. A system as claimed in claim 9, wherein said data transmitter means comprises a radio transmitter and said data receiver means comprises a complementary radio receiver for radio frequency communication of said first satellite position information and said differential error.

11. A system as claimed in claim 9, wherein said data transmitter means comprises a radio transmitter for radio frequency communication of said differential error, and a hardware interconnection port for physical communication of said first satellite position information to said calculator, said data receiver means comprising a complementary radio receiver for receiving said differential error and a complementary port for receiving said first satellite position information.

12. A system as claimed in claim 9, 10 or 11, wherein said third satellite position information receiver is arranged at said base station and a receive antenna of same is arranged at said reference location about said base station.

13. A system as claimed in any one of claims 6 to 12, wherein said satellite position information is obtained from one or more satellites of a satellite positioning system and said distance calculations include corrections for longitude, latitude and altitude data received from said satellite(s).

14. A system as claimed in claim 13 when dependent on claim 9, wherein said third satellite position information receiver can simultaneously receive satellite position information from a plurality of satellites, said control means thereby determining a like plurality of said differential errors and forwards same to said calculator for error correction prior to determination of said variable position.

15. A system as claimed in claim 11, wherein said radio transmitter means and said radio receiver means are

adapted for communication of said first satellite position information with said differential error.

16. A system as claimed in claim 15, wherein said portable calculator comprises a microcontroller means and a memory means arranged for storage of said satellite position information, a keypad means operable by said user to select any of said fixed positions and for enabling said actual position information received from said second satellite position information receiver to said microcontroller means for retention in said memory means, said complementary port connecting to said microcontroller means, and a display means interconnected to said microcontroller means for displaying said distance to said user.

17. A system as claimed in claim 16, wherein said display means comprises a 2-dimensional pixel array and said memory means can be input with map data including said fixed positions and encompassing areas at which said actual position can be located to thereby enable visual display to said user of the relative relationship between said actual position and any one or more of said fixed positions.

18. A system as claimed in claim 17, wherein said map data is provided to said calculator via said complementary port or preprogrammed in a portable memory device.

19. A system as claimed in claim 17 or 18, wherein said fixed positions relate to selected positions about a golf course and said actual position is a position of a golf ball on said course, whereby said calculator enables said user to determine the distance between said ball and one of said selected position, so as to thereby provide an indication to a golf player of the particular golf club that should be selected for the next stroke of the ball to approach said one selected position.

20. A system as claimed in claim 19, wherein said fixed positions are pin hole and dog-leg positions about said golf course, which are entered into said control means

for supply to said calculators and are updated contemporaneously with variations in said fixed positions.

21. A system as claimed in any one of claims 9 to 20, wherein said distance can be determined to an accuracy of ± 2-5 metres.

22. A system as claimed in any one of claims 9 to 21 wherein said calculator further determines a bearing to be travelled from said variable position to said fixed position.

23. A system as claimed in claim 22 when dependent on claim 19 or 20 wherein said calculator determine.. for the next stroke, a correction bearing based on said variiable position resulting from the previous stroke and the previous variable position.

24. A portable distance calculator for use with the invention as claimed in any one of the preceding claims.

AMENDED CLAIMS

[received by the International Bureau on 13 April 1993 (13.04.93); original claims 1 - 24 replaced by amended claims 1 - 16 (3 pages)]

1. A transportable distance calculator comprising:

a (first) satellite position information receiver for determining satellite position information of said calculator;

memory means for retaining fixed position information of one or more fixed positions;

receiver means for real-time reception of satellite positional error information; and

processor means for firstly using said error information to correct said calculator satellite position information in real-time and to thereby determine and display a distance between said calculator and a selected one of said fixed positions.

2. A distance measuring system comprising:

at least one transportable distance calculator as claimed in claim 1; and

a base station comprising:

a second satellite position information receiver for continuously determining satellite position information of said base station;

control means for comparing said base station satellite information with a predetermined reference position of said base station to determine said positional error information in real-time; and

transmitter means for transmitting said error information for reception by said receiver means.

3. A system as claimed in claim 2, wherein said control means comprises a store for retaining said fixed position information and a communication means for transferring said fixed position information to said calculators.

4. A system as claimed in claim 3, wherein said communication means comprises a hardware interconnection port connectable to a complementary port in one of said

calculators for direct transfer of said fixed position information.

5. A system as claimed in claim 3, wherein said communication means interconnects said store with said transmitter means for transmission of said fixed position information to said calculators.

6. A system as claimed in claim 2, wherein said fixed position information comprises survey data one or more of said fixed positions.

7. A system as claimed in claim 2, wherein said fixed position information is determined by operating one of said calculators at one or more said fixed positions, and simultaneously error correcting said fixed positions with said positional error information prior to storing said fixed positions in said memory means from which it can be transferred to said control means.

8. A system as claimed in claim 7, wherein said fixed positions are transferred by displaying said fixed position information on said calculator and manually entering same into said control means.

9. A system as claimed in claim 2, wherein said transmitter means and said receiver means utilize radio frequency communication from said base station to said calculator.

10. A system as claimed in claim 2, wherein said second satellite position information receiver can simultaneously receive satellite position information from a plurality of satellites from which said control means can thereby determine a like plurality of positional error information which is thereby transferred to said calculator for correcting said calculator satellite position information obtained from the same satellite.

11. A system as claimed in claim 2, wherein said fixed positions are positions about a golf course and said calculator is operable at a golf ball position on said golf

course whereby the lineal distance between the golf ball and a selected one of said positions is determined and substantially instantaneously displayed on a display means to a user of said calculator.

12. A system as claimed in claim 11, wherein said display means comprises a 2-dimensional pixel array and said memory means can be input with map data including said fixed positions and encompassing areas at which said golf ball can be positioned to thereby enable visual display to the user the relative relationship between the golf ball position and any one or more of said fixed positions.

13. A system as claimed in claim 11, wherein having determined said distance, said calculator indicates to the user a particular golf club that should be selected for a next stroke of the golf ball to approach a selected one of said fixed positions.

14. A system as claimed in claim 1, wherein said calculator further determines and displays a bearing from said calculator to said selected one fixed position.

15. A system as claimed in claim 11, wherein said fixed positions are pin hole and dog-leg positions about said golf course.

16. A system as claimed in claim 1, wherein said calculator is configured in a unitary hand-held portable form.

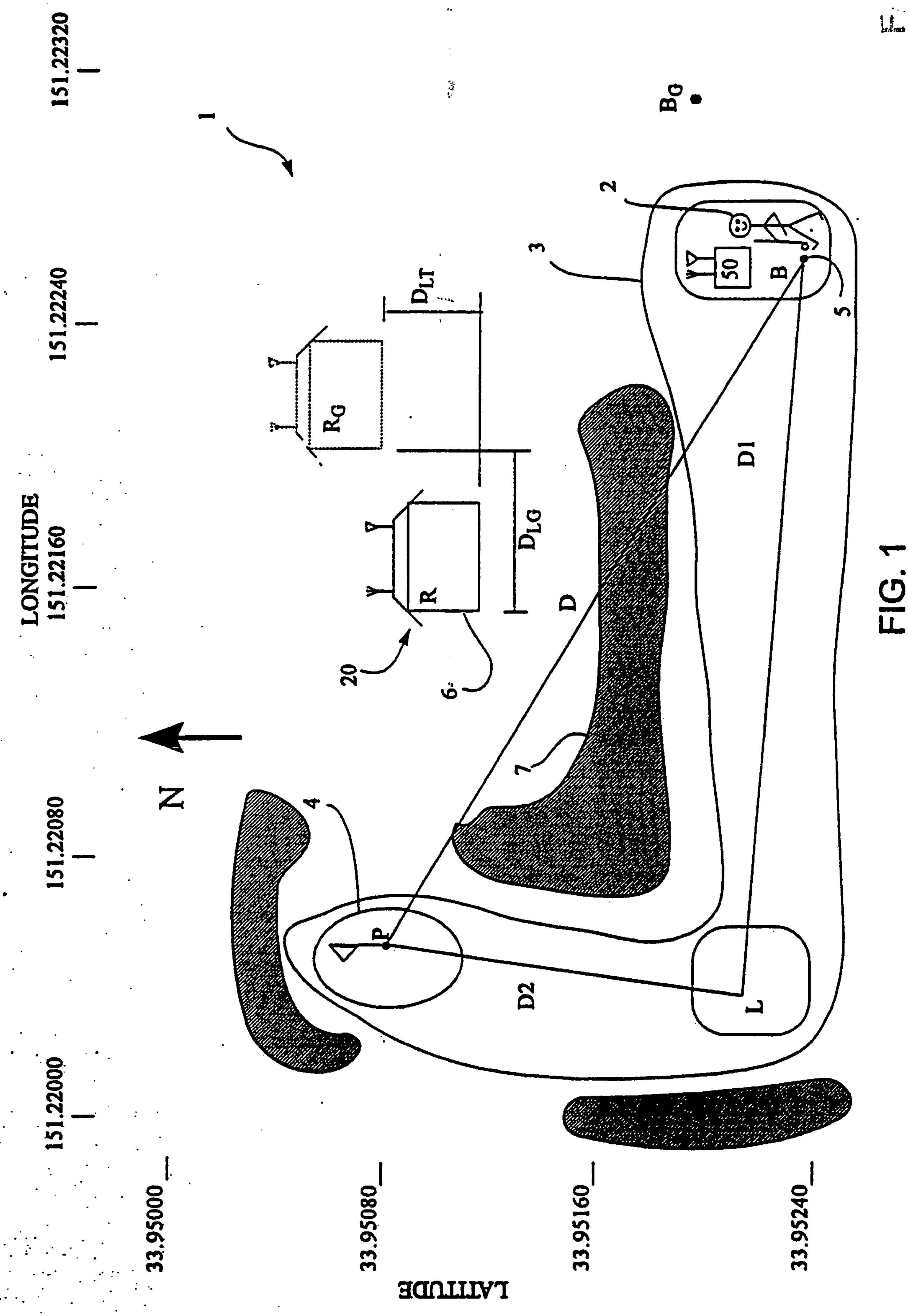
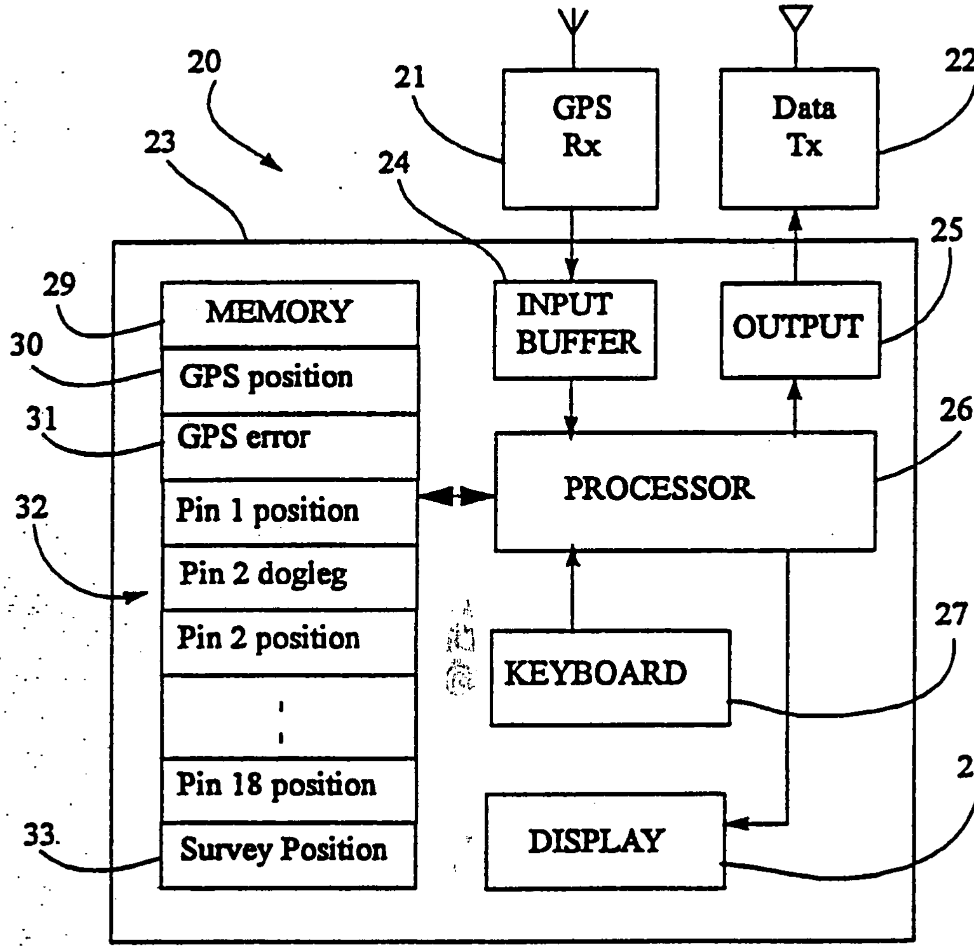
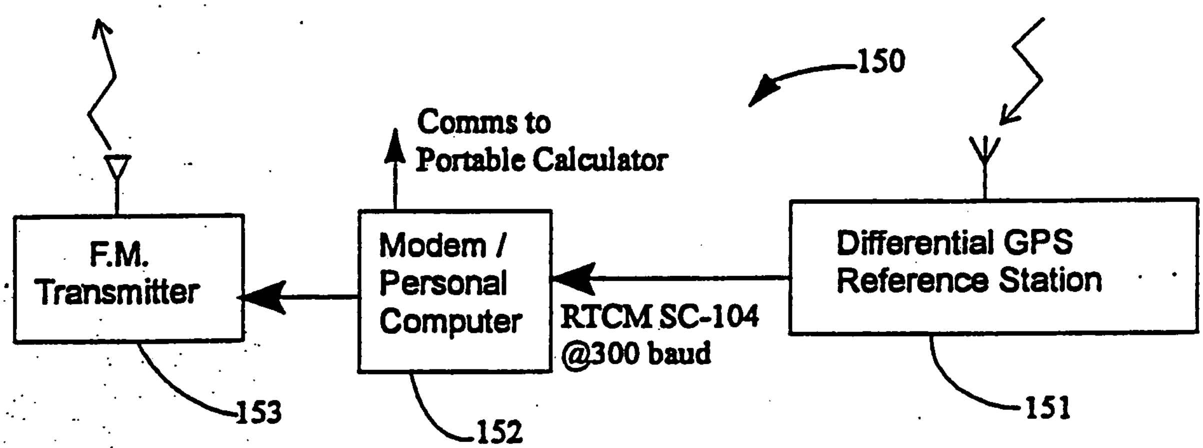

LONGITUDE
151.22160
151.22000
151.22080
151.22240
151.22320
LATITUDE
33.95000
33.95080
33.95160
33.95240
N
1
2
3
4
5
6
7
20
50
B
B_G
R
R_G
D_{LT}
D_{LG}
D
D1
D2
P
L

FIG. 1



20
21
22
23
24
GPS
Rx
Data
Tx
25
29
MEMORY
INPUT
BUFFER
OUTPUT
30
GPS position
31
GPS error
26
PROCESSOR
32
Pin 1 position
Pin 2 dogleg
Pin 2 position
27
KEYBOARD
Pin 18 position
28
DISPLAY
33
Survey Position

FIG. 2



150
Comms to
Portable Calculator
F.M.
Transmitter
Modem /
Personal
Computer
Differential GPS
Reference Station
RTCM SC-104
@300 baud
153
152
151

FIG. 7

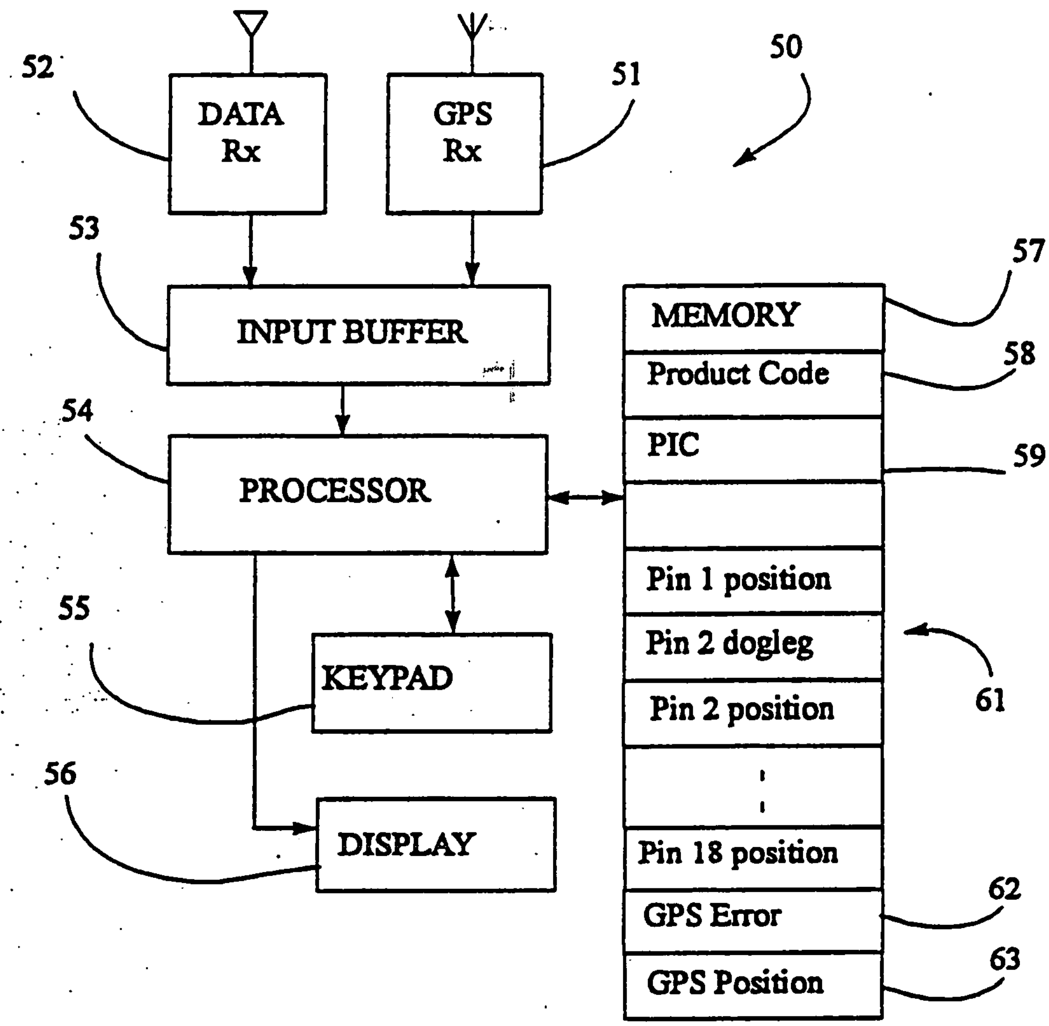

50
52
51
DATA
Rx
GPS
Rx
53
INPUT BUFFER
57
MEMORY
58
Product Code
54
PIC
59
PROCESSOR
Pin 1 position
55
Pin 2 dogleg
KEYPAD
Pin 2 position
61
56
DISPLAY
Pin 18 position
62
GPS Error
63
GPS Position

FIG. 3

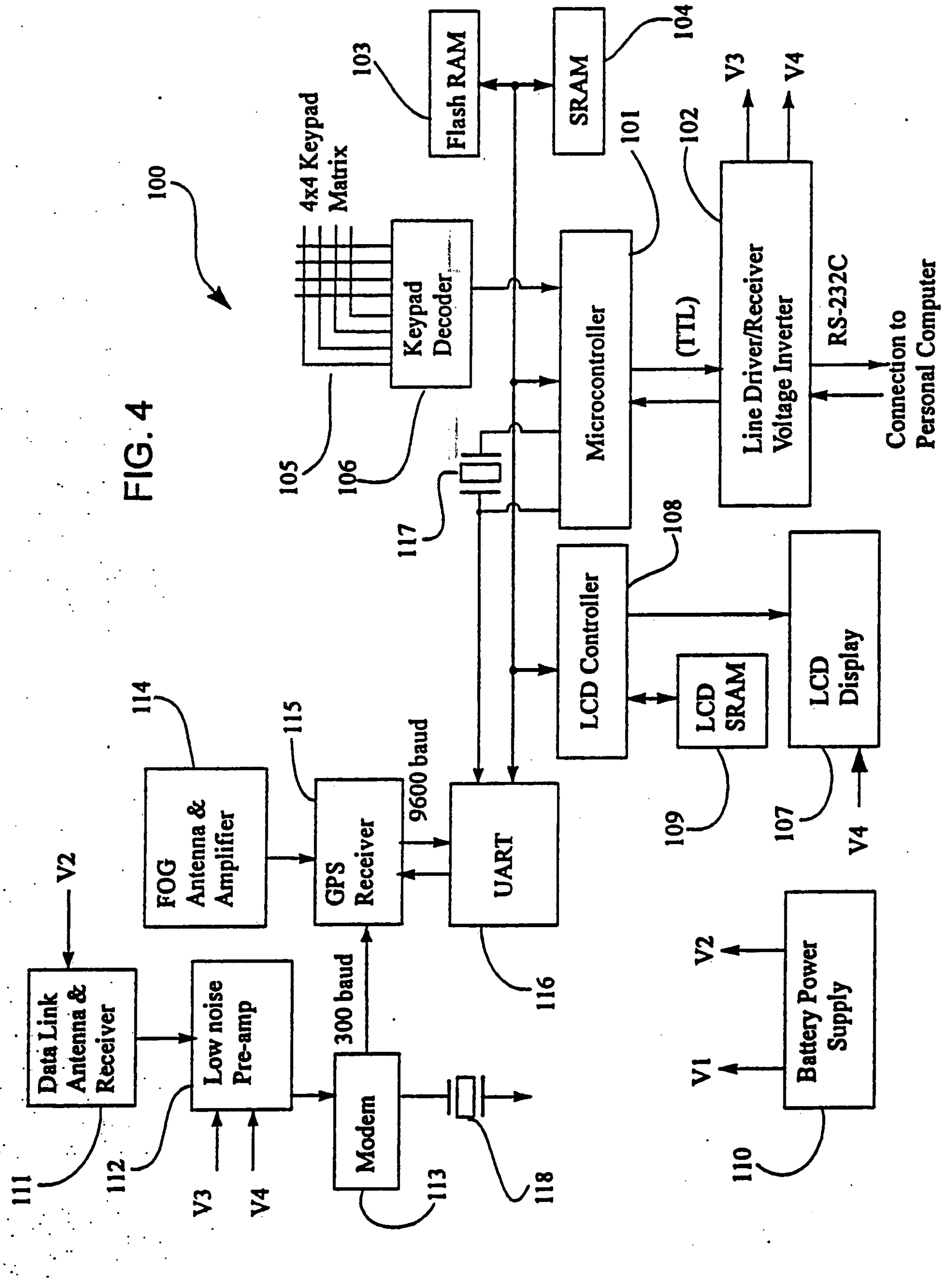

100
4x4 Keypad Matrix
Keypad Decoder
105
106
Flash RAM
103
SRAM
104
101
Microcontroller
(TTL)
102
Line Driver/Receiver Voltage Inverter
V3
V4
RS-232C
Connection to Personal Computer
117
108
LCD Controller
LCD SRAM
109
LCD Display
107
V4
114
FOG Antenna & Amplifier
115
GPS Receiver
9600 baud
UART
116
V2
Data Link Antenna & Receiver
111
Low noise Pre-amp
112
V3
V4
300 baud
Modem
113
118
Battery Power Supply
V2
V1
110

FIG. 4

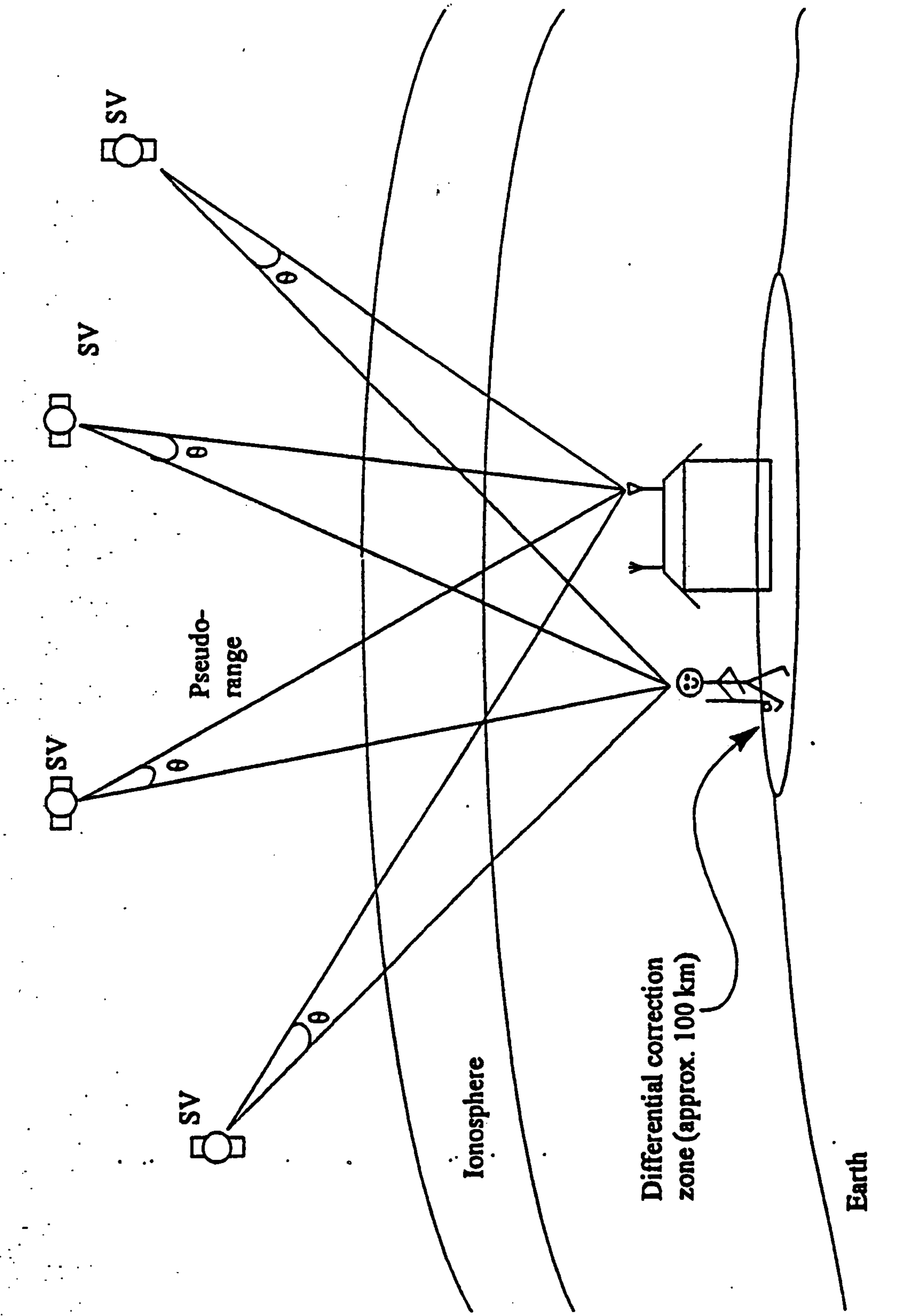

SV
SV
SV
SV
θ
Pseudo-range
Ionosphere
Differential correction zone (approx. 100 km)
Earth

FIG. 5

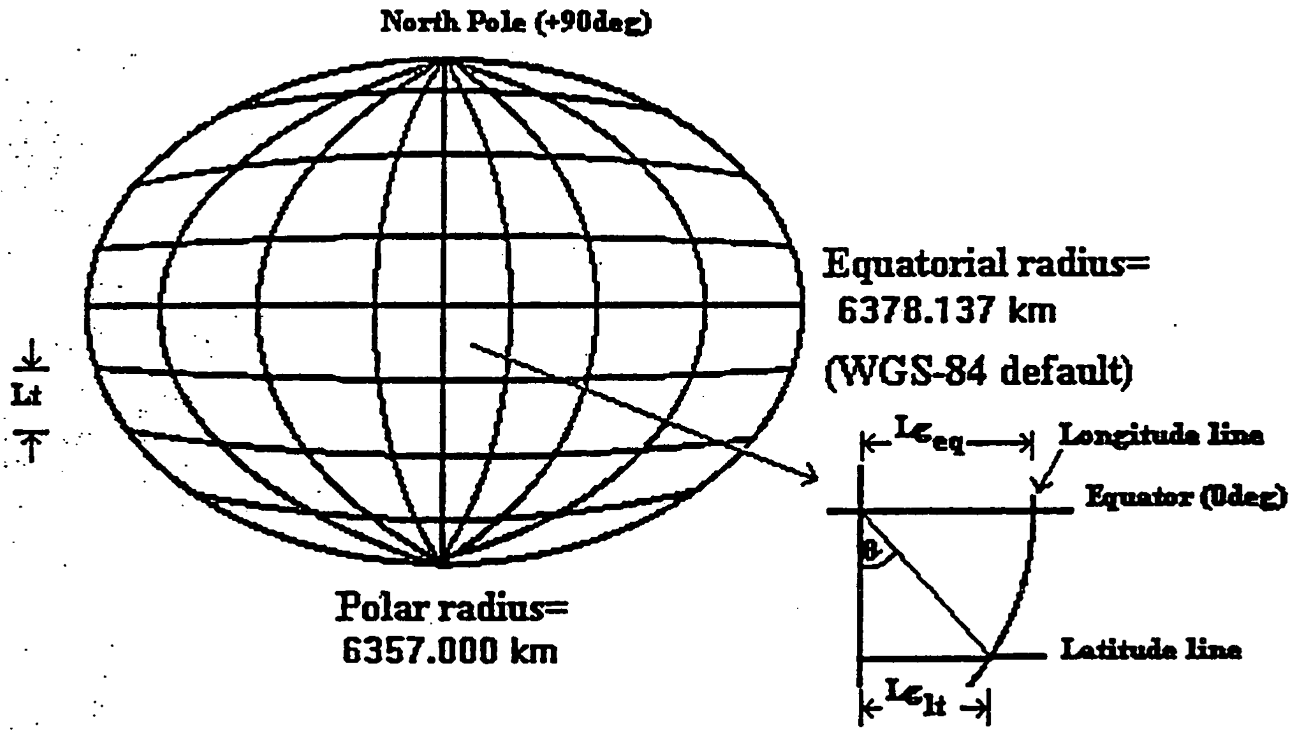

North Pole (+90deg)
Equatorial radius=
6378.137 km
(WGS-84 default)
Lt
Lg_{eq}
Longitude line
Equator (0deg)
θ
Latitude line
Lg_{lt}
Polar radius=
6357.000 km

FIG. 6

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl.[5] G01S 5/10, 11/02

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC : G01S 5/10, 5/14, 11/00, 11/02

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
AU : IPC as above

Electronic data base consulted during the international search (name of data base, and where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to Claim No.
P,X	GB,A, 2249202 (OSAMU) 29 April 1992 (29.04.92) Abstract. Claims.	1-23
X	GB,A, 2213339 (THE SECRETARY OF STATE FOR DEFENCE) 9 August 1989 (09.08.89) Abstract. Figure.	1-23
X	US,A, 4973970 (REESER) 27 November 1990 (27.11.90) Abstract, Column 5 lines 3/17	1-23

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier document but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
12 February 1993 (12.02.93)	16 FEB 1993 (16.02.93)

Name and mailing address of the ISA/AU	Authorized officer
AUSTRALIAN PATENT OFFICE PO BOX 200 WODEN ACT 2606 AUSTRALIA	R. CHIA
Facsimile No. 06 2853929	Telephone No. (06) 2832185

C(Continuation).	DOCUMENTS CONSIDERED TO BE RELEVANT	
Category*	Citation of document, with indication, where appropriate of the relevant passages	Relevant to Claim No.
X	US,A, 4894655 (JOGUET et al) 16 January 1990 (16.01.90) Abstract. Figures.	1-23
X	US,A, 4812991 (HATCH) 14 March 1989 (14.03.89) Abstract. Figure 1, Claim 1.	1-23
X	EP,A, 444738 (PHILIPS ELECTRONIC AND ASSOCIATED INDUSTRIES LIMITED) 4 September 1991 (04.09.91) Abstract. Figures.	1-23
P,X	AU,A, 14997/92 (NAVSYS CORPORATION) 12 November 1992 (12.11.92) Abstract. Figure 1.	1-23
X	AU,A, 63995/90 (AUSPACE LIMITED) 18 April 1991 (18.04.91) Abstract. Figure 1. Page 5 line 20/Page 6 line 6.	1-23

Box I. **Observations where certain claims were found unsearchable (Continuation of Item 1 of first sheet)**

This international search report has not established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☒ Claim Nos.: 24
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

The invention referred to is indeterminate and it is not drafted in accordance with Rule 6.3.

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II **Observations where unity of invention is lacking (Continuation of item 2 of first sheet)**

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims

2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest.

☐ No protest accompanied the payment of additional search fees.

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report		Patent Family Member					
GB	2249202	NONE					
GB	2213339	NONE					
US	4973970	CA	2016309	EP	408179		
US	4894655	CA	1297972	EP	283353	FR	2611399
US	4812991	AU IL	74356/87 82387	CA WO	1268239 8706713	EP	264440
EP	444738	GB	2241623	US	5119102		
AU	14997/92	CA	2066831	EP	512789		
AU	63995/90	NONE					

END OF ANNEX